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DIVISION OF CHEMISTRY

THE BASICITY OF TEXAS SOILS

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*Dean, School of Veterinary Medicine.
** In cooperation with U. S. Department of Agriculture.
***In cooperation with the School of Agriculture.

This Bulletin is a result of the studies of some chemical problems connected with the investigations of cotton root rot being made by the Division of Plant Pathology and Physiology. Laboratory methods were needed for estimating the amounts of acid or sulphur required to bring experimental soils approximately to a desired degree of acidity. Information was needed regarding the amounts of acid or sulphur required to make acid various kinds of soil. This Bulletin discusses the basicity of Texas soils, and the amounts of acid or sulphur required to make them acid. It contains a map showing the location of regions of soils of different degrees of basicity, together with a discussion of methods and other details. Basicity is related to soil fertility, soil acidity, possible needs of the soil for lime, and the effects of certain fertilizers, as well as to root rot.

CONTENTS

BULLETIN NO. 400 DECEMBER, 1929

THE BASICITY OF TEXAS SOILS

By G. S. Fraps and E. C. Carlyle

When the cotton root rot investigations of the Division of Plant Pathology and Physiology showed that root rot is less prevalent on acid soils than on neutral or on basic soils (Bulletin 389), a number of chemical problems resulted. It became desirable to have a laboratory method for estimating the amount of acid required to bring a soil to a desired degree of acidity. It was necessary to consider the practicability of making the soil acid as a control measure; to know how much acid is required to make acid various soil types or soils in various regions, or to know how much sulphur should be used in case advantage was taken of the biological oxidation of sulphur to sulphuric acid. It was desired to know the approximate basicity of soil types in various areas in Texas, to furnish a basis for ascertaining if there was any relation between them and the occurrence of cotton root rot. This Bulletin is a result of chemical studies intended to furnish some of the desired information. The material is, however, of interest in other connections.

The degree of basicity or acidity of the soil is one of its most important characteristics. Soils with a high basicity are limestone soils. Limestone soils are generally fertile and durable. Soils with a moderate degree of basicity contain some lime and are neutral or nearly so. Soils with a low degree of bascity have a tendency to become acid. Highly acid soils, while favorable to a few crops, are generally unfavorable to most cultivated crops, especially legumes. Soils which have a high degree of acidity are usually treated with lime, especially when alfalfa, clover, and other legumes are to be grown.

The basicity or acidity of soils may be related to the occurrence and destructiveness of cotton root rot or other plant diseases in various sections of the State. The basicity is also related to the effect of fertilizer on the reaction of soils. Some fertilizer materials, such as sulphate of ammonia, have a tendency to cause the soil to become acid. Sulphate of ammonia reacts with the replaceable bases in the soil silicates; the ammonia replaces lime or magnesia (chiefly lime), producing sulphate of lime or magnesia, and silicates which contain ammonia. The ammonia may be used as such by plants, leaving hydrogen in its place, thereby producing an acid silicate. If bases are available, this acid silicate is neutralized. Part of the ammonia is oxidized to nitric acid before it is taken up by plants, and this also requires bases to neutralize it. The net result is that sulphate of ammonia and similar salts tend to make the soil acid. Whether or not the soil becomes acid depends on the amount of sulphate of ammonia used and on the power of the soil to neutralize the acidity. Acid soils are usually not so well suited to the growth of cultivated crops, especially legumes, as neutral or slightly alkaline soils.

Some other fertilizer materials, such as nitrate of soda, tend to make the soil basic. The sodium of nitrate of soda reacts with the replaceable lime or magnesia in silicates in the soil, producing calcium or magnesium nitrates, with sodium in place of part of the lime or magnesia in the silicates. When the nitrogen is taken up by plants, it leaves part of the calcium or magnesium as carbonates, which are basic substances.

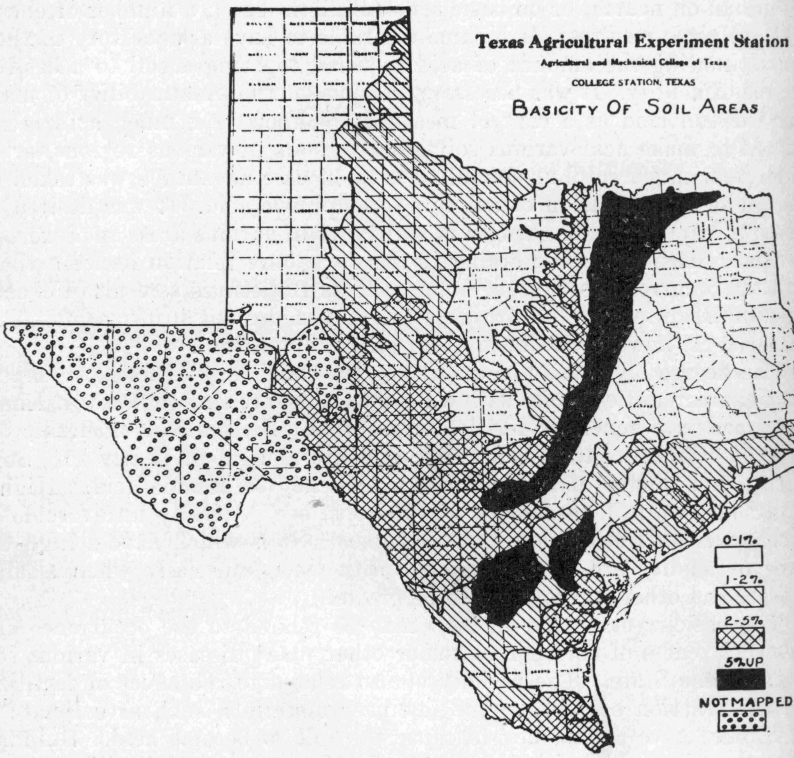

Figure 1. Map showing the predominant character of upland soils, as regards basicity.

Here the use of nitrate of soda may tend to make an alkaline soil still more alkaline. The complex sodium silicates produced are liable to be highly colloidal and to cause the soil to run together and to have other undesirable characteristics. Whether this will occur depends on the character of the soil and other circumstances. The use of nitrate of soda on acid soils tends to reduce the acidity. A mixture of nitrate of soda and sulphate of ammonia in proper proportions will not affect the acidity of the soil.

The importance of these characteristics of sulphate of ammonia and nitrate of soda depends upon various conditions, and a discussion of this matter is outside the scope of this Bulletin.

BUFFER CAPACITY OF SOILS

The buffer capacity of a soil is closely related to the basicity. It is measured by the amount of acid or alkali required to change the intensity of the acidity or alkalinity to a desired extent. The intensity of acidity or alkalinity is measured by the hydrogen ion concentration, expressed by pH.

When a soil is treated with an acid, the bases in the soil use up part or all of the acid. At first the soil may not become acid, but further additions of acid will produce acidity or increase the intensity of the acidity if the soil is already acid. The amount of acid required to bring the soil to a given intensity of acidity (pH) depends upon the character of the soil, and may be termed the "buffer capacity for acid." A soil with a pH of 7.0 is neutral; below 7.0 it is acid; and above 7.0 it is alkaline. The pH is a logarithmic function, so that the arithmetical value of the intensity of the reaction increases rapidly; taking pH 7.0 as 1, the relative acidity is 10 for pH 6, 100 for pH 5, 1000 for pH 4, 10,000 for pH 3, while the relative alkalinity is 10 for pH 8, 100 for pH 9, 1000 for pH 10, and 10,000 for pH 11.

Charltin, according to Pierre, designates the total buffer capacity of soils toward acid as the number of cubic centimeters of normal sulphuric acid necessary to bring 100 grams of soil to a pH of 4.5, and he calls the total buffer capacity towards base the number of cubic centimeters of normal barium hydroxide necessary to bring 100 grams of soil to a pH of 9.5. The buffer capacity per 1.0 pH he defines, for acid, as the total buffer capacity to acid divided by the original pH of the soil less 4.5; and for base the total buffer capacity to base divided by 9.5 less the original pH of the soil. Pierre uses similar definitions, but calls the buffer capacity per 1.0 pH the specific buffer capacity. [Jour. American Soc. Agron. 19 (1927), 332.]

One cubic centimeter normal sulphuric acid to 100 grams of soil is equal to 490 parts per million of sulphuric acid added to the soil or 160 parts per million of sulphur or 500 parts per million of calcium carbonate.

The work reported in this Bulletin is chiefly in terms of parts per million of sulphur (in sulphuric acid) required by the soil to produce the desired pH. This method of reporting the results was adopted for the reason that the use of sulphur (as such) to change the reaction of the soil was under consideration, and the analyses were desired in terms of the material studied. It also seems to the writers that expression of the results in terms of some definite chemical substance, in parts per million of the soil, is more desirable than in terms of volume of acid of a certain strength to a certain quantity of soil. The latter form of expression requires the use of three arbitrary terms not necessarily related, and seems complicated from a mental standpoint. The statement of buffer capacity as parts per million of sulphur required by the soil, or calcium carbonate in the soil equivalent to the buffer capacity, or in some similar way, seems more logical and perhaps easier to understand.

METHOD OF ESTIMATION OF THE BUFFER CAPACITY FOR ACIDS

After some preliminary work, the method described below was adopted to test the large number of soils to be used. The method provides for testing a large number of samples with various amounts of acid on succeeding days, each treatment depending upon the previous one, until the desired figures are attained. Checks are made at the final points. As most of the soils selected were low in buffer capacity, the beginning point was acid equivalent to 200 parts per million of sulphur in the soil.

Method: Weigh 8 grams of the soil into a 150 cc. beaker and add 10 cc. of .01N sulphuric acid. Allow to stand for 24 hours and add 90 cc. of water. Allow to stand till clear and determine pH. If the pH is more than 4.7 or less than 4.3, run pH according to Table 1. When there is a dash in the table, discontinue. In each case, after the soil has been in contact with acid for 24 hours, add water to bring the total volume to 100 cc. and determine pH.

The first column in Table 1 is pH acid to run; the second column is amount of acid to add to 8 grams of soil.

Table 1.—Acid to use in treating soils for buffer capacity.

Parts per million sulphur in soil equivalent to acid used	Quantity of acid to use for 8 grams of soil	If pH is over 4.7 make test for	If pH is under 4.3 make test for
50	2.5 c.c. .01 acid + 2.5 c.c. water		
100	5.0 c.c. acid + 5.0 c.c. water		50
200	10.0 c.c. .01 N	500	100
300	15.0 c.c. acid		
400	20.0 c.c. acid		300
500	25.0 c.c. acid	1000	400
600	30.0 c.c. acid		
700	35.0 c.c. acid		600
800	40.0 c.c. acid	900	700
900	45 c.c. acid		
1000	50 c.c. acid	2000	800
1200	60 c.c. acid		
1500	75 c.c. acid	1800	1200
1800	90 c.c. acid		
2000	100 c.c. acid	4000	1500
2500	12.5 c.c. 0.1 N acid		
3000	15.0 c.c. 0.1 N acid	3500	2500
3500	17.5 c.c. 0.1 N acid		
4000	20.0 c.c. 0.1 N acid	10000	3000
5000	25.0 c.c. 0.1 N acid		
10000	50.0 c.c. 0.1 N acid	50000	5000
20000	100.0 c.c. 0.1 N acid		
50000	25.0 c.c. 1.0 N acid	100000	20000
100000	50.0 c.c. 1.0 N acid	200000	
200000	100.0 c.c. 1.0 N acid		

RELATIONS OF THE BUFFER CAPACITY TO OTHER PROPERTIES

The analyses of a number of Texas soils were averaged in groups according to their buffer capacity (Table 2). The analyses include the amounts of 0.02N sulphuric acid neutralized by the soils expressed as calcium carbonate, termed basicity .02N; the amounts of 0.2N acid neutralized by the soil, termed basicity 0.2N; and the lime and magnesia soluble in strong hydrochloric acid (Hilgard's method). The methods used for 0.2N basicity and .02N basicity are described in another part of this Bulletin.

It is seen from Table 2 that as the average buffer capacity increases, the basicity, the lime, and magnesia also increase. The increase is not regular, which is to be expected. The bases neutralized in the soil by .02N sulphuric acid or 0.2N nitric acid, are not entirely in forms suitable to act as buffers to prevent the soil from becoming acid. Parts of these bases may be calcium carbonate or basic silicates, which may neutralize some acid without becoming acid, but part of these leave acid silicates when the base is extracted, and part of the bases come from silicates which are decomposed by the strong acid used. The proportions of these three groups vary in different soils, so that the proportions of lime or magnesia soluble in strong acid which can help keep the soil from becoming acid vary with different soils and can be ascertained only by direct tests.

It is difficult to compare the figures in Table 2 on account of their being expressed in different units. For this reason the buffer capacity, the basicity by .02N acid, the basicity by 0.2N acid, the lime and magnesia, and the sums of the lime and magnesia, were calculated to their equivalent in parts per million of calcium carbonate. The results are presented in Table 3.

This table also contains the buffer capacity expressed as percentage of the basicity estimated by the two acid methods and of the lime plus magnesia calculated to calcium carbonate.

An examination of Table 3 shows that the buffer capacity averages 24.3 to 92.4 per cent of the basicity measured by .02N acid. A smaller percentage of the basicity determined by 0.2N acid than by .02N acid is available to act as a buffer (20.8 to 42 per cent) and a very much smaller percentage (6 to 23 per cent) of the lime and magnesia soluble in strong acids. In each case the percentage increases with the basicity of the soil. That is to say, as a rule, the more lime and magnesia present in the soil, the greater is the percentage which can be used to neutralize acids and act as a buffer to prevent the soil from becoming acid.

These results mean that most of the lime and magnesia dissolved by strong acids from soils is present as silicates, which do not have the power of neutralizing weak acids. This also applies to the bases dissolved by 0.2N nitric acid, and to a less extent to the bases dissolved by 0.02 acid. In other words, the bases that are dissolved by .02N acid (.02N basicity) bear a closer relation to the buffer action of the soils

Table 2.—Average relation of other analyses to buffer capacity in parts sulphur per million of soil.

Number averaged	Group based on buffer capacity	Buffer capacity						.02 N basicity %	0.2 N basicity %	Lime %	Magnesia %	pH
		Nearest 4.7		Just above 4.7		Just below						
		Sulphur p. m.	pH (end)	Sulphur p. m.	pH (end)	Sulphur p. m.	pH (end)					
34	51– 150............	118	4.7	107	5.3	230	4.1	.152	1.8	0.15	0.14	5.8
76	151– 250............	205	4.6	136	5.5	329	4.1	.194	2.6	.16	.17	6.0
35	251– 350............	301	4.6	216	5.3	402	4.1	.265	3.1	.18	.23	6.4
47	351– 450............	401	4.6	254	5.6	482	4.3	.344	4.4	.34	.18	6.4
47	451– 550............	500	4.6	300	5.7	626	4.3	.468	6.6	.31	.27	6.4
32	551– 650............	599	4.6	513	5.2	748	4.3	.605	9.4	.46	.31	6.7
27	651– 750............	700	4.4	537	5.3	817	4.3	.572	8.1	.38	.29	6.8
29	751– 850............	797	4.5	538	5.4	919	4.3	.673	8.3	.38	.30	6.6
15	851– 950............	900	4.7	511	5.8	1053	4.2	.668	10.3	.76	.33	6.9
22	951– 1050............	1000	4.9	618	5.6	1450	4.2	.730	13.8	.73	.41	6.8
13	1051– 1250............	1131	4.9	1000	5.2	1340	4.2	.815	15.1	.61	.52	7.2
22	1251– 1550............	1436	4.6	1054	5.7	1572	4.1	.776	17.5	.77	.57	7.2
5	1551– 1850............	1780	4.6	1000	6.3	1920	4.4	.913	15.1	.87	.48	7.1
8	1851– 2050............	1988	5.1	1400	6.5	1800	4.2	.942	23.8	4.39	.60	7.3
8	2051– 2550............	2475	4.3	1750	6.5	3000	4.2	.837	18.7	.72	.79	6.9
4	2551– 3050............	2950	4.6	2333	5.7	3550	4.2	....	21.9	1.54	1.12	7.6
4	3051– 3550............	3425	4.7	3000	5.6	3700	4.0	.970	18.7	.78	.75	7.4
6	3551– 4050............	3900	5.7	3500	5.4	3800	4.2	.510	35.2	2.20	.63	7.1
4	4051– 5050............	4875	4.5	3333	6.5	4500	4.7	....	24.9	1.21	1.12	7.1
6	5051–10050............	8333	4.8	6000	6.5	1200	3.0	....	39.1	1.79	1.00	7.3
14	10051–20050............	15786	4.1	13083	6.7	19286	3.5	1.000	62.1	3.90	.89	7.5
9	20051–30050............	27333	4.5	22143	6.4	31667	3.4	....	80.6	4.16	.97	7.3
10	30051–40050............	37500	4.4	34857	6.7	38800	3.8	1.00	90.5	4.68	.88	7.4
6	40051–50050............	49167	5.6	27500	6.9	52500	3.4	....	99.9	13.10	.91	7.6

Table 3.—Buffer capacity and other analyses expressed as carbonate of lime in parts per million.

Number Averaged	Group based on buffer capacity	Buffer capacity	.02 basicity	0.2 basicity	Lime as $CaCO_3$	Magnesia as $CaCo_3$	Lime and magnesia	Buffer Capacity		
								in % of .02N basicity	in % of 0.2N basicity	in % of lime and magnesia
34	51– 150	369	1520	1800	2680	3420	6150	24.3	20.5	6.0
76	151– 250	641	1940	2600	2860	4220	7080	33.0	24.7	9.1
35	251– 350	941	2650	3100	3210	5700	8910	35.5	30.4	10.6
47	351– 450	1253	3440	4400	6070	4460	10530	36.4	28.5	11.9
47	451– 550	1563	4680	6600	5540	6700	12240	33.4	23.7	12.8
32	551– 650	1872	6050	9400	8220	7690	15910	30.9	19.9	11.8
27	651– 750	2188	5720	8100	6790	7190	13980	38.2	27.0	15.7
29	751– 850	2491	6730	8300	6790	7440	14230	37.0	30.0	17.5
15	851– 950	2813	6680	10300	13570	8180	21750	42.1	27.3	12.9
22	951–1050	3125	7300	13800	13040	10170	23210	42.8	22.6	13.5
13	1051–1250	3534	8150	15100	10890	12900	23790	43.4	23.4	14.9
22	1251–1550	4488	7760	17500	13750	14140	27890	57.8	25.6	16.2
5	1551–1850	5563	9130	15100	15540	11900	27444	60.9	36.8	20.3
8	1851–2050	6213	9420	23800	78410	14880	93290	66.0	26.1	6.7
8	2051–2550	7734	8370	18700	12860	19590	32450	92.4	41.4	23.8
4	2551–3050	9219	....	21900	70410	27780	98190	....	42.1	9.4

than the bases dissolved by .2N or stronger acid. The silicates of calcium and magnesium are not so readily attacked by .02N acid as by 0.2N acid.

There is a close relation between the buffer capacity for acid and basicity as measured by .02N acid. The correlation coefficient is .79±.02 for 164 soils.

EFFECT OF TIME ON BUFFER CAPACITY

The buffer capacity of soils for acids may become greater with the lapse of time; that is, the soils treated with acid may become less acid with the process of time. To test this, soils with tested buffer capacity were allowed to remain in contact with acid. The results are given for various periods of time in Tables 4 and 5. There is an appreciable

Table 4.—Effect of time on pH of soils to which acid was added.

Laboratory No.	Amount of acid expressed as sulphur in parts per million	Regular method	pH after 2 days	pH after 4 days	pH after 6 days	pH after 8 days
6208	200	4.1	4.5	4.6	4.6	4.7
7613	600	4.3	4.7	4.9	5.0	5.0
12584	1800	4.5	4.9	5.1	5.1	5.3
12520	300	5.0	5.3	5.3	5.4	5.6
12674	700	5.1	5.3	5.4	5.5	6.1
9376	300	4.8	5.1	5.2	5.2	5.2
8340	400	4.5	4.6	4.7	4.7	4.7
	Average	4.6	4.9	5.0	5.1	5.2

Table 5.—Effect of time on pH of soils to which acid has been added.

Laboratory No.	Amount of acid expressed as sulphur in parts per million	Regular method	After 30 days	After 60 days	After 5½ months	After one year
12588	600	4.1	4.5	4.5	4.8	4.5
12676	300	4.3	4.7	4.7	....	4.6
12586	400	3.9	4.1	4.2	5.3	4.3
18216	900	2.9	4.1	4.1	4.2	4.2
9349	500	3.7	5.0	5.1	5.1	5.3
9333	300	4.3	4.4	4.5	4.5	5.1
12667	300	6.6	6.4	6.0	5.3	4.9
6976	700	4.0	4.7	4.8	4.8	4.3
18911	700	4.8	4.9	4.9	5.0	5.1
9378	600	3.8	4.5	4.5	4.4	4.5
7708	800	5.6	6.5	6.7	6.7	6.5
18539	200	4.7	4.7	4.8	4.9	4.6
18207	500	4.7	4.7	4.7	4.9	4.7
18211	600	4.9	4.9	4.9	5.1	4.9
9376	500	3.6	4.4	4.4	4.1	4.0
6268	300	5.0	6.2	6.2	6.1	....
18228	500	4.4	4.6	4.6	4.6	4.5
18208	300	4.0	4.1	4.1	4.2	4.4
18205	500	4.3	4.7	4.6	4.6	4.3
17440	600	4.1	4.9	4.8	4.3	4.2
18210	600	5.1	5.9	5.8	6.7	6.0
18217	500	4.8	4.6	4.6	4.6	4.7
9329	300	3.9	4.5	4.6	4.4	3.7
12590	500	4.4	4.9	4.7	4.3	4.3
Average	the above 24 soils	4.4	4.9	4.9	4.7	4.7
Average	23 soils (second set)	4.7	5.4	....	....	....
Average	23 soils (third set)	4.7	5.3	....	....	....
Average	20 soils (fourth set)	4.6	5.5	....	....	....

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average decrease in acidity in two days as compared with 24 hours in the regular method used. This decrease continues up to about 6 days, varying with the soil. After that, while some few soils decrease in acidity in 5½ months to one year, the usual change is in the limit of error and the average change is small.

While the change in 6 days with some soils is small, with others it is large. It averages in 30 days, from 0.5 to 0.7 pH with the three sets of soils used in the work. The relation of the buffer capacity for acid as determined in about 24 hours to the buffer capacity of the soil after several weeks is therefore irregular, and it is not possible to state exactly the amount of the buffer capacity after 30 days from the estimation in 24 hours. In one set of 24 soils, the change in pH in 21 to 28 days was very small; pH averaged 5.3 for 21 days and 5.4 for 28 days. A contact of soil and acid for 24 hours is not long enough, though 6 days may be sufficient for most soils.

RELATION OF BUFFER CAPACITY TO THE AMOUNT OF SULPHUR REQUIRED TO CHANGE THE ACIDITY

When flowers of sulphur, ground sulphur, or some other form of free sulphur is placed in the soil, the sulphur is oxidized to sulphuric acid, and the soil will become acid if a sufficient quantity of sulphur is used. The change is chiefly a biological process brought about by bacteria, which varies with the temperature, the activity of the organisms, and other conditions. For a review of this process, see Joffe, Bulletin 374, New Jersey Experiment Station.

For the purpose of ascertaining the effect of sulphur on the acidity of soils and its relation to their buffer capacity, mixtures were made of soil, sulphur, and water and left at room temperature for various periods of time, water being added from time to time.

Table 6 shows only the minimum amounts of sulphur which were required to bring the pH of the soils tested to about 4.5 in the time specified. A large number of other tests were included in the experiments.

Considerable amounts of sulphur were needed to change the pH in the first 30 days; while the amounts of sulphur required increase with the amounts of acid used for this purpose in the laboratory test, the relations are not close.

At the end of 60 days, the same acidity (pH) was secured with smaller amounts of sulphur, although they were considerably larger than the amounts of acid required.

A still smaller amount of sulphur was required at the end of 90 days to produce the same degree of acidity.

Soils with a buffer capacity of 200 for a pH of 4.5 required approximately 400 parts per million of sulphur to effect a corresponding change in the pH of the soils in 120 days. A buffer capacity of 250 to 400 required about 500 parts per million of sulphur; a buffer capacity of 500

Table 6.—Effect of acid and sulphur in parts per million on acidity of the soil. (pH)

Laboratory No.	Buffer capacity next pH 4.5	pH	Buffer capacity next below pH 4.5	pH	30 days		60 days		90 days		120 days	
					Amount Sulphur	pH	Amount Sulphur	pH	Amount Sulphur	pH	Amount Sulphur	pH
6010	200	4.4			2500	4.5	1000	4.3	750	4.7	750	4.5
12586	200	4.7	400	3.9	2500	4.5	750	4.2	500	4.3	500	4.1
18539	200	4.7			1000	5.7	750	4.7	500	4.5	500	4.2
9329	250	4.3	300	3.9	2500	4.9	500	4.5	500	4.5	500	4.2
9333	250	4.4	300	4.3	2500	4.5	750	4.2	750	4.1	500	4.1
18208	250	4.1			2500	5.7	2500	4.2	1000	4.7	750	4.2
9349	300	4.5	400	4.1	2500	4.4	500	4.6	500	4.3	500	4.2
12676	300	4.3			2000	4.3	600	4.1	500	4.5	500	4.3
9376	300	4.5	400	4.3	2500	4.3	500	4.7	500	4.3	500	4.6
9381	300	5.0	400	3.5	3000	5.9	1200	5.3	900	5.2	600	4.0
18229	300	4.7	400	4.3	2500	5.2	1000	4.6	750	4.2	500	4.4
9353	350	4.6	400	4.1	2500	4.5	750	4.6	500	4.7	500	4.8
6268	350	4.7	400	4.2	4000	4.3	1600	4.5	800	4.5	800	4.3
12668	400	4.3	500	3.9	2500	4.8	1000	4.5	750	4.1	500	4.3
18205	400	4.5	500	4.3	2500	5.3	1000	4.5	750	4.3	500	4.7
18228	400	4.9			2500	4.5	1000	4.3	750	4.7	750	4.5
9378	500	4.3	600	3.8	3000	4.4	1200	4.4	600	4.3	600	4.5
9380	500	4.3	400	4.2	5000	4.6	1500	4.3	1000	4.1	1000	3.8
5938	500	4.4	600	4.2	5000	5.0	5000	4.3	1000	4.5	1000	4.2
12590	500	4.4	600	4.3	2500	5.3	2500	4.0	500	4.5	500	4.6
7160	500	4.5	600	4.3	1200	5.3	1600	4.7	1200	4.5	800	4.6
18216	500	4.4			1500	4.7	1500	3.9	1000	4.2	1000	4.1
18230	500	4.9	600	4.3	2500	4.9	750	4.7	500	4.5	500	4.6
7227	500	4.9			3000	5.7	600	4.7	600	4.2	600	4.1
18911	500	4.5	600	4.1	4000	4.7	1200	4.6	800	4.5	800	4.3
12588	600	4.1			2000	4.5	1500	4.1	1000	4.1	1000	3.6
17440	600	4.1			2500	4.6	750	4.5	500	4.1	500	4.3
9354	600	4.2			3000	4.5	1200	4.5	900	4.2	900	4.3
12667	600	4.3	2500	2.8	2500	6.1	2500	4.5	1000	4.5	1000	4.3
6976	600	4.4	700	4.0	5000	4.3	2000	4.7	1000	4.1	1000	4.3
7352	600	4.4			3000	4.8	3000	4.1	1200	4.3	800	4.5
7613	600	4.4	800	4.0	2500	4.9	750	4.9	750	4.7	750	4.9
9168	600	4.4	700	4.0	4000	5.5	4000	4.5	4000	4.3	1800	4.3
7360	600	4.5	800	4.0	3000	5.3	3000	4.3	1200	4.4	900	4.3
18211	700	4.5	800	4.1	4000	5.5	1600	4.9	800	4.7	800	4.8
18217	700	4.5	800	4.1	2500	5.1	2500	4.4	750	4.7	500	4.3
7172	800	4.3			4000	6.7	4000	6.1	4000	4.4	4000	4.7
18210	800	4.5			4000	6.8	4000	5.7	4000	4.7	4000	4.3
12659	800	4.7			4000	4.7	4000	4.4	1200	4.5	800	4.6
7708	1000	4.4			4000	6.4	4000	4.7	1600	4.9	1600	4.8
7266	1000	4.5	900	4.3	5000	7.1	5000	5.6	5000	4.5	5000	4.2
12641	1500	4.3	1400	3.7	6000	6.7	6000	6.5	6000	4.9	2400	4.5
12647	1500	4.3	1400	4.2	6000	4.5	2400	4.5	1800	4.3	1800	4.3

required about 700; a buffer capacity of 700 required about 800; a capacity of 800 to 1000 required about 1600 to 2400 parts per million of sulphur. These represent the approximate minimum quantities. There is considerable variation, and it does not appear possible to predict the exact amount of sulphur necessary to produce a desired degree of acidity. This renders difficult the proper use of sulphur to change the soil acidity to a point near the toxic limit of acidity, since if too much sulphur is used, the soil may become too acid, with consequent damage to the crops.

The amount of sulphur required to secure the desired degree of acidity of the soil when the buffer capacity of the soil was over 800 parts per million of sulphur, was much higher in proportion than when the buffer capacity was lower. This may be due to accidental variations in the sulphur-oxidizing organisms in the soils studied, but it may also mean that sulphur-oxidizing organisms are less active in soils of high basicity than in those of low basicity or that the larger amounts of sulphur may delay the activity of the oxidizing organisms, or that reduction of sulphuric acid may occur.

BASICITY OF TEXAS SOILS

When a soil is brought in contact with an excess of acid, some of the lime, magnesia, and other bases of the soil go into solution and neutralize part of the acid. The amount of acid neutralized may readily be measured by titrating the excess acid with a solution of a base. The amount of base which goes into solution depends on the kind of acid, the strength of the acid, the proportion of soil to acid, the time, temperature, and other conditions.

The basicity of Texas soils as measured by the methods here described was studied for the purpose of securing a method to make a quick preliminary grouping of soils with respect to probable buffer capacity. The basicity of a large number of samples had already been tested in the laboratory and could be used in the preliminary sorting of the soils, after their relations were ascertained.

The term basicity is here used to mean the bases which neutralize dilute nitric acid, sulphuric acid or similar acids, as measured by titration of the acid after contact with the soil. It is recognized that this does not correctly represent the real basicity of the soil, as pointed out already in this Bulletin. A routine method is used in connection with the estimation of active phosphoric acid and active potash, in which one part soil is brought in contact with 10 parts of 0.2N nitric acid 5 hours at 40° C; a portion of the filtrate, after dilution and boiling to expel carbon dioxide, is titrated with 0.1N sodium hydroxide and phenolphthalein. The results are expressed as acid consumed by the soil, in percentage of the acid used, or as 0.2N basicity, in terms of calcium carbonate equivalent to the acid consumed. An acid consumed of 10 per cent is equivalent to a basicity of 1.0 per cent of the soil; that is, the bases which neutralize the acid under the conditions of the test, would be equivalent to 1 per cent calcium carbonate in the soil. All the 0.2N acid is neutralized by some very basic soils, in which case the exact basicity may be estimated by a subsequent digestion with normal acid, though in routine work the results are frequently expressed as 10 per cent basicity.

Method for Estimation of Basicity of Soils Low in Basicity

The estimation of basicity or acid consumed described above is not highly accurate, though it is considered to be sufficiently accurate for the purpose for which it is used. It requires too long a period of time for the approximate estimation of basicity when made alone and is not sufficiently accurate for soils low in basicity. Accordingly, experiments were made to devise, (a) a quick method for basicity, (b) a method for soils with low basicity.

Quick Method for Basicity: Sulphuric acid was used, for the reason that for the purpose of changing the soil reaction in root rot investigations, sulphuric acid would be used, possibly as such but more probably formed in the soil by the bacterial oxidation of sulphur. Five grams of soil were digested with 50 cc. of 0.2N sulphuric acid under the conditions tested. The liquid was filtered, and 10 cc. of the filtrate was diluted with about 75 cc. of water; it was then boiled about a minute to expel carbon dioxide, and titrated with 0.2N sodium hydroxide.

Four sets of twelve soils each were tested under various conditions and the average results are given in Table 7.

Table 7.—Average effect of time and temperature on average basicity as measured by 0.2 N sulphuric acid, expressed as carbonate of lime.

	Set 1 %	Set 2 %	Set 3 %	Set 4 %
Room temperature:				
10 minutes	1.21	1.53	1.34	1.17
30 minutes, 40° C	1.24	1.58	1.38	1.20
60 minutes, 40° C	1.23	1.58	1.42	1.55
2 hours, 40° C	1.31	1.63	1.52	1.31
Usual method	1.47	1.48	1.37	1.41
Number of samples	13	12	12	12

There are differences between the average results secured by the four methods, the shorter method giving the lowest results. The results are comparative and not absolute. The use of ten minutes with shaking at room temperature appeared suitable and was adopted. The results are reported as acid consumed (10 minutes) or 0.2 basicity (10 minutes) to distinguish it from the other method.

Method for Soils Low in Basicity: The following method was tested. Treat 10 grams of soil with 100 cc. of 0.02N sulphuric acid for the time and at the temperature specified. Filter, heat 50 cc. to boiling for one minute, and titrate with 0.04N sodium hydroxide and phenolphthalein.

One cc. 0.02N acid equals .02 per cent basicity expressed as calcium carbonate. Report as .02N basicity.

Basicity by the above method was determined in 36 soils by three different methods; (A) 24 hours at room temperature, (B) one hour at room temperature, and (C) 15 minutes with shaking. The average results are given in Table 8. The results vary somewhat with the method of treatment, the 5 hours at 40° giving the highest results, and one hour at room temperature the lowest. Shaking 15 minutes at room temperature gives higher results than one hour without shaking.

Table 8.—Average effect of time and shaking on basicity measured by 0.02N sulphuric acid

	Basicity %
A-24 hours	.341
B-1 hour	.236
C-15 minutes shaking	.284
D-Basicity by 0.2 N sulphuric acid 5 hours at 40° C.	.430
Average difference A-B	.105
Average difference C-B	.048
Number of samples	360

RELATION OF BASICITY TO BUFFER CAPACITY

The analyses of a number of soils grouped according to basicity as measured by 0.2N acid were averaged, and the results are given in Table 9. Soils with a basicity of 0 to 0.5 per cent have a buffer capacity for pH 4.5 of 100 to 1000 parts per million of sulphur in the soil, with an average of 309. Soils with a basicity of 0.51 to 1.0 per cent have an average capacity of 669 parts per million of sulphur, varying from 100 to 1500 parts per million. These two groups also contain acid soils, the pH of the soil varying from 4.3 to 7.4 with an average of about 6.5. The amounts of acid or sulphur required to change the pH of many soils in these two groups are within the limits of practicability.

The buffer capacity (expressed as sulphur) of soils with a basicity of 1 to 2 per cent varies from 200 to 5000 parts per million, with an average of 1746. The amounts of sulphur or acid required to change the acidity of these soils are mostly too high to be of practical significance. The pH of these soils did not fall below 5.5, and therefore probably none of these soils were acid enough to cause damage.

Soils with a basicity of more than 2.0 per cent are neutral or slightly alkaline in reaction, and require large amounts of sulphur or acid to make them acid.

BASICITY AND BUFFER CAPACITY OF SOIL REGIONS IN TEXAS

The basicity of a large number of Texas soils has been determined by 0.2N acid. By means of these analyses, the Soil Survey reports, and the regional soil map prepared by W. T. Carter, of the Soil Survey, a map has

Table 9.—Average analysis of soils averaged in groups according to basicity.

	Basicity 0–.5	Basicity .51–1.0	Basicity 1.0–2.0	Basicity 2.0–5.0	Basicity over 5.0
Average basicity, as carbonate of lime, per cent	.264	.766	1.45	3.0	8.3
Buffer capacity per million for pH 4.5 average	309	669	1746	7358	33800
Buffer capacity per million for pH 4.5 minimum	100	100	200	1500	18000
Buffer capacity per million for pH 4.5 maximum	1000	1500	5000	25000	120000
Buffer capacity per million for pH 5.5 average	224	466	1650	5050	....
		4.4			
Buffer capacity per million for pH 4.1 average	382	776	1900	7739	....
.02 acid consumed, per cent	.25	.59	.81	.83	....
Acid-soluble lime, per cent	.23	.37	.70	1.39	6.63
Acid-soluble magnesia, per cent	.18	.29	.47	1.10	9.24
pH of original soil, extremes	4.3–7.8	4.6–7.4	5.5–7.4	6.7–7.4	7.3–7.6
pH of original soil, average	6.3	6.5	....	7.3	7.5
Number of soils	187	120	82	26	47

been prepared showing the prevailing basicity of the surface of the upland soils in various sections of Texas (see Figure 1). There are decided variations in the cahracteristics of the soils in all sections, and there are soils which vary widely from the basicity of the area as shown in the map. The map merely gives a generalized idea of the basicity of the soils in the various areas, and the fact that local variations occur must not be forgotten.

The map also corresponds to the upland soils. As a general rule, alluvial soils in Texas are more basic than upland soils.

Soils with low basicity: The soils with a basicity of less than 1 per cent occur chiefly in the East Texas timber country, the East Texas flatwoods section, the West Cross Timbers, and the soils of the High Plains or Staked Plains. There are also areas in Brooks, Willacy, Mason, and Llano counties.

As has already been pointed out (see Table 9) these soils have a buffer capacity of 100 to 1000 parts per million of sulphur. They have a lower lime and magnesia content than the other soils. Some of these soils are acid. The acid soils occur in the East Texas timber country or flat woods section. Acid soils which need lime for legumes are likely to be found in this section. Some few soils may be made acid by continuous use of sulphate of ammonia in fertilizers. It might be practicable to make some of these soils acid by the use of sulphur, if such practice is found advisable to control cotton root rot.

Soils with High Basicity: The highly-basic calcareous soils occur chiefly in the Black Waxy Prairie Belt, though there are also areas around McMullen and Bee counties. These soils tend to be slightly alkaline in reaction. They have a high buffer capacity. These soils are not likely to become acid, or to need lime for legumes. The amount of sulphur required to make them acid would be entirely too large to be practical.

Soils with Moderate Basicity: The soils of a large portion of the State have a basicity of 1 to 2 per cent. These soils are basic, have a moderate buffer capacity, and are neutral in reaction. They generally contain enough lime for legumes and have so high a buffer capacity that the use of sulphur to change the pH to be acid would be impractical.

SUMMARY AND CONCLUSIONS

1. The basicity and acidity of the soil are closely related to their agricultural value. Basic soils are generally better suited to the growth of agricultural crops than acid soils.
2. The basicity of the soil as the term is here used is measured by the amount of acid neutralized by the soil expressed as carbonate of lime. The methods for basicity are described and studied.

3. The buffer capacity as here described is the amount of acid required to change the intensity of the acidity to a desired extent. The buffer capacity for bases as here discussed is expressed as parts per million of sulphur in the form of sulphuric acid required to change the soil to a pH of about 4.6. The methods are described.
4. The buffer capacity averages from 24 to 92 per cent of the basicity measured by .02N acid and a smaller percentage, 21 to 42 per cent of the basicity, measured by .2N acid. Only from 6 to 23 per cent of the lime and magnesia soluble in strong acid acts as buffer under the conditions here discussed. In each case the percentage available for buffer action increases with the basicity of the soil.
5. A large proportion of the lime and magnesia dissolved by strong acid from soils is present as silicates which do not have the power of neutralizing weak acids.
6. The buffer capacity is larger if the acid is allowed to remain in contact with the soil 6 to 8 days than in 24 hours, the routine method.
7. Elemental sulphur is oxidized in the soil to sulphuric acid, which consumes the bases of the soil. At room temperature, the change occurs somewhat slowly. It is difficult to estimate exactly the amount of elemental sulphur required to produce a desired change in the acidity of the soil.
8. Soils with a buffer capacity of 200 for a pH of 4.5 require approximately 400 parts per million of sulphur to effect in 120 days, the corresponding change in the pH of the soils tested. A buffer capacity of 250 to 400 requires about 500 parts per million of sulphur; a buffer capacity of 700 requires about 800; a buffer capacity of 800 to 1000 requires about 1600 to 2400 parts per million of sulphur to effect a similar change in 120 days.
9. There is an approximate relation between the basicity and buffer capacity for acid. Soils with a basicity of 0.5 per cent have a buffer capacity, for the pH of 4.5, of 100 to 1000 parts per million of sulphur in the soil, with an average of 309. Soils with a basicity of .51 to 1.0 per cent have an average buffer capacity of 669 parts per million of sulphur. Those with a basicity of 1 to 2 per cent have an average buffer capacity of 1746 and a higher basicity brings a corresponding high buffer capacity.
10. A map is given showing the occurrence of soils of different degrees of basicity of the surface soil.

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